# PACT: Performance Analysis of Cell Tracking

## User Manual

PACT is a repository of code that provides a way to compute the performance evaluation metrics, SFDA and ATA, described in the paper “Comprehensive and standardized metrics for the performance evaluation of cell-tracking algorithms.”

This manual describes

1) **Functions in the repository.**
2) **Input file formats for tracking-results and ground-truth data.**
3) **Using the ViPER tool for authoring ground-truth.**
4) **Auxiliary Scripts**

### 1) Functions in the repository

The primary function in the repository used to carry out performance analysis is called main.m. This function makes calls to the functions pm_sfda.m and pm_ata.m, as well as other helper functions, in order to compute the performance metrics. This function can be invoked with the following MATLAB command:

```
[SFDA, ATA] = main(groundtruthFileString, trackingResultsFileString)
```

Inputs to main.m:

a) groundtruthFileString contains the path to a ground-truth file, which should be in one of the formats described in Section 2.
b) trackingResultsFileString contains the path to a tracking-results file, which should be in one of the formats described in Section 2.

Outputs of main.m

a) [SFDA,ATA], a vector of two values, the SFDA and ATA.

### 2) Input file formats for tracking-results and ground-truth data

2.1) Standard .csv format:

For both tracking-results and ground-truth data, one option is to put either into a standard .csv format. We describe the standard .csv format below, and provide an example. Note that minX and minY refer to the minimum horizontal and vertical (respectively) positions of the bounding box (with specified width and height).

The .csv format:

```
cellIndex_1
frameIndex_1,minX,minY,width,height
frameIndex_2,minX,minY,width,height
...
frameIndex_final,minX,minY,width,height
cellIndex_2
frameIndex_1,minX,minY,width,height
...
```

An example:

```
1
1,10,11,25,23
2,12,12,25,24
3,14,13,25,25
4,16,15,25,23
5,17,16,25,25
2
1,45,200,10,14
2,46,198,12,13
3,47,197,12,14
3
1,150,152,30,20
2,152,154,31,21
3,154,156,30,21
4,156,158,34,22
5,158,160,30,21
```

The .csv input file may also only contain the first 3 fields in each row, in cases where tools used only provide cell centroid information. In this case, it is assumed that instead of the usual fields

frameIndex, minX, minY

the given fields become

frameIndex, centroidX, centroidY

where centroidX and centroidY refer to the horizontal and vertical (respectively) positions of the cell's centroid. As the SFDA and ATA metrics are heavily dependent on bounding box information, in cases where only cell centroids are provided, a fixed bounding box size is used for each cell; in these cases, the same fixed bounding box size is also substituted in for each ground-truth cell. This fixed bounding box size allows for the computation of approximate SFDA and ATA in cases where only cell centroid positions are given. We have experimentally seen that the metrics are not highly sensitive to this choice of fixed bounding box size; however, a user may view and modify the fixed value on line 136 of the function src/main.m. Note that, in general, if either of the input files passed to the main.m function contain only cell centroids, both the results and ground-truth are given a fixed bounding box size.

2.2) TIAM .mat tracking-results input file:

The MATLAB .mat workspace produced by running TIAM on a cell video (of the form filename.mat ) can also be used as tracking-results input. During a run of TIAM, a user will enter a size conversion coefficient ("micrometers per pixel") that allows TIAM to produce results in micrometer units. This same conversion coefficient must be given as a final parameter when TIAM results are used. In this case, the call to compute the metrics is written:

```
[SFDA, ATA] = main(groundtruthFileString, trackingResultsFileString,
sizeConvertCoefficient)
```

where the trackingResultsFileString is the path of the MATLAB .mat workspace file of the form filename.mat.

An example from the benchmark folder:

```
main('../benchmark/exp1_gt.csv', '../benchmark/exp1_results.mat', 0.439)
```

2.3) ViPER .txt ground-truth input file:

The ViPER tool is an open source, easy-to-use tool for authoring ground-truth (and was used by the authors of this project for all ground-truth). A description of ViPER and how to use it to author ground-truth are given in Section 3. ViPER gives as an output a .txt file that can be used directly by the main.m function. In this case, the groundtruthFileString input parameter should be replaced with the ViPER output file, filename.txt.

## 3) Using the ViPER Tool for Authoring Ground-Truth

The ViPER tool is an open source tool that can be used to author ground-truth from a video of cells. This tool was used by the authors of this project for all ground-truth and is recommended. It can be downloaded from:

[http://viper-toolkit.sourceforge.net/](http://viper-toolkit.sourceforge.net/)

We provide below a list of instructions for using ViPER to author ground-truth:

**Instructions for generating ground-truth with ViPER:**

1) Have the relevant time-series images in mpeg movie format. We use ImageJ to save time-series images as AVI movie (uncompressed). Then we use the trial version of 'Avi to Mpeg' converter to convert to Mpeg.
2) Use viper-gt.jar to initiate the ViPER user-interface.
3) Load the relevant Mpeg movie: Media -> Add Media File. The movie frame appears in the left side panel. The bottom panel has the scroller. The right panel shows ground-truth information.
4) Define variables to set up the template for ground-truth annotation:

   a. Window -> Schema Editor.
   b. Click 'Add Descriptor' button at the bottom. Have 'Data Type' as 'OBJECT'. We typically name the object as 'cell'.
   c. Attributes: There are two types of attributes. One is the cell ID and the other is the bounding box. Cell ID doesn't change over frames (static). The bounding box values could change over frames (dynamic).
      i. For the cell ID do the following: Click the 'Add Attribute' button at the bottom. Could choose to change the name from 'Attr0' to your choice, say 'cell'. Keep the 'Data Type' as 'svalue'. Keep the 'dynamic' property as 'false'.
      ii. For the bounding box do the following: Click 'Add Attribute' button at the bottom again. Could choose to change the name from 'Attr1' to your choice, say 'box'. Change the 'Data Type' as 'bbox'. Change the 'dynamic' property to 'true'.
   d. Be sure to define the template as described above to ensure that the PACT can correctly parse the ViPER ground-truth.

5) Ground-truth annotation:

   a. Be sure to ensure that all the tab buttons colored green and not yellow or red. Click 'Create' at the bottom of the panel. This will create a row for entering information on the first cell that is to be manually tracked. Make sure to check the box under the 'V' tab. Enter a name under the tab 'Attr0' (or 'cell'). Make sure to select the entry under the 'Attr1' (or 'box') tab. At this stage you can draw a box around the first cell you want to manually track. When the box is colored red, the box can still be edited, by moving the corners or by moving the edges that will be highlighted in pink. However, if you click elsewhere on the movie frame it turns green and can't edited any further. You will have to click on/in the box to edit it again. Or you can select the entry under the 'Attr1' (or 'box') tab.
   b. If the box under the tab 'P' has been checked, then bounding box from the previous frame gets copied on to the subsequent frames if

one moves to the subsequent frames. The box can be edited as explained above in the subsequent frames. After tracking the cell completely, make sure to uncheck the boxes under tabs 'P' and 'V' if there are more frames in the movie. You can create another entry for tracking the next cell as explained above and continue on.

c. You can save the annotation file in ViPER at any stage. File -> Save.

6) Export the ground-truth annotation: File -> Export in Old Format to export in the 'txt' format that will be used by PACT's main.m function (as described in Section 2.3).

A ViPER tutorial (http://viper-toolkit.sourceforge.net/docs/gt/4.0/tutorial/) may also be useful for any additional instructions regarding the authoring of ground-truth.

The ViPER official documentation can be found at:
http://viper-toolkit.sourceforge.net/docs/

## 4. Auxiliary Scripts

The directory src/auxiliaryScripts in the PACT repo contains additional scripts to convert output files from the CellTrack, DYNAMIK, and Imaris tools into the standard .csv input format that can be directly used by the main.m function (see Section 2.1). The conversion functions are: imaris2csv.m, celltrack2csv.m, and dynamik2csv.m. These scripts can be called as follows:

- imaris2csv(imarisCsvFileString,outputFileName,sizeConversionCoefficient)
- celltrack2csv(celltrackTxtFileString,outputFileName)
- dynamik2csv(dynamikMatFileString,outputFileName)

where the first argument of each function is the path to each tool's output file, the second argument is the path to the produced .csv file, and the sizeConversionCoefficient is the micrometer-per-pixel size ratio (only required for Imaris conversion). Note that the imarisCsvFile format must be created by saving Imaris' output in Excel format with 'position' information and converting this into a .csv file. One can use Excel for this conversion by saving the Excel file in .csv format. The csv file should contain the following information in columns in that order: TrackID, Frame number, Position X, Position Y. Tracking results from Volocity can also be saved and converted to this format for use by PACT.